LOUDNESS OF SPEAKING: THE EFFECT OF THE INTENSITY OF SIDE-TONE UPON THE INTENSITY OF THE SPEAKER

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Contract N7onr-411, Task Order No. 1, Project 20-K-2

Report 411-1-4

Designation Number NR-782-004

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Prepared for
Special Devices Center
Office of Naval Research

June 12, 1948

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Summary

Sixteen subjects read intelligibility tests while wearing headphones. Each subject read four tests, one at each of four levels of intensity of the side-tone in his headphones. A constant level of background noise was in the headphones, only the amplification of the speaker-induced signal varying. A panel of listeners heard the recordings, in a noise-filled room (110-114 db) in the manner of an intelligibility test. Also through the tracings of a graphic level recorder the intensity of the speaker's readings of the test items was measured. Analysis showed that speaker increased in vocal intensity with diminished side-tones, and that intelligibility scores likewise increased when the speaker heard less intense side-tones.

1. Introduction and Method

Flight students frequently find the experiences of a side-tone bothersome when they begin to talk over aircraft radio and interphone. Many of them learn with surprise that their home telephones have such a speaker signal, although considerably attenuated. Later the student is taught to use the side-tone advantageously. It becomes his guide to vocal intensity as he talks loudly enough to produce a "good, strong side-tone." It and kinesthetic sensations are his only aids to proper voice intensity when the noise of the cockpit completely masks his air-conducted speaking.

Two related questions arise. Does the level of amplification or intensity of the side-tone affect the intensity with which the speaker talks? Does it affect his intelligibility? This report finds that level of side-tone affects both.

Sixteen naval officers served as subjects. Each one read four lists from lists 1-12 (Form A) and 1-4 (Form B) of the Voice Communication Laboratory Multiple-Choice Intelligibility Test. Thus in reading,

each list was used by four talkers, or, putting it differently the first four readers used lists 1-16; the second four used the same lists, etc. The talkers used carbon hand-held service microphones. A technician instructed the readers in standard placement of the microphone (lightly touching the lips) and, using a simulated test, paced them in optimal speed of reading an intelligibility test.

The reader wore a service headset with conventional dynamic headphones and doughnut ear cushions. A constant level of in-circuit noise was in the headphones all of the time, comparable to that induced by an

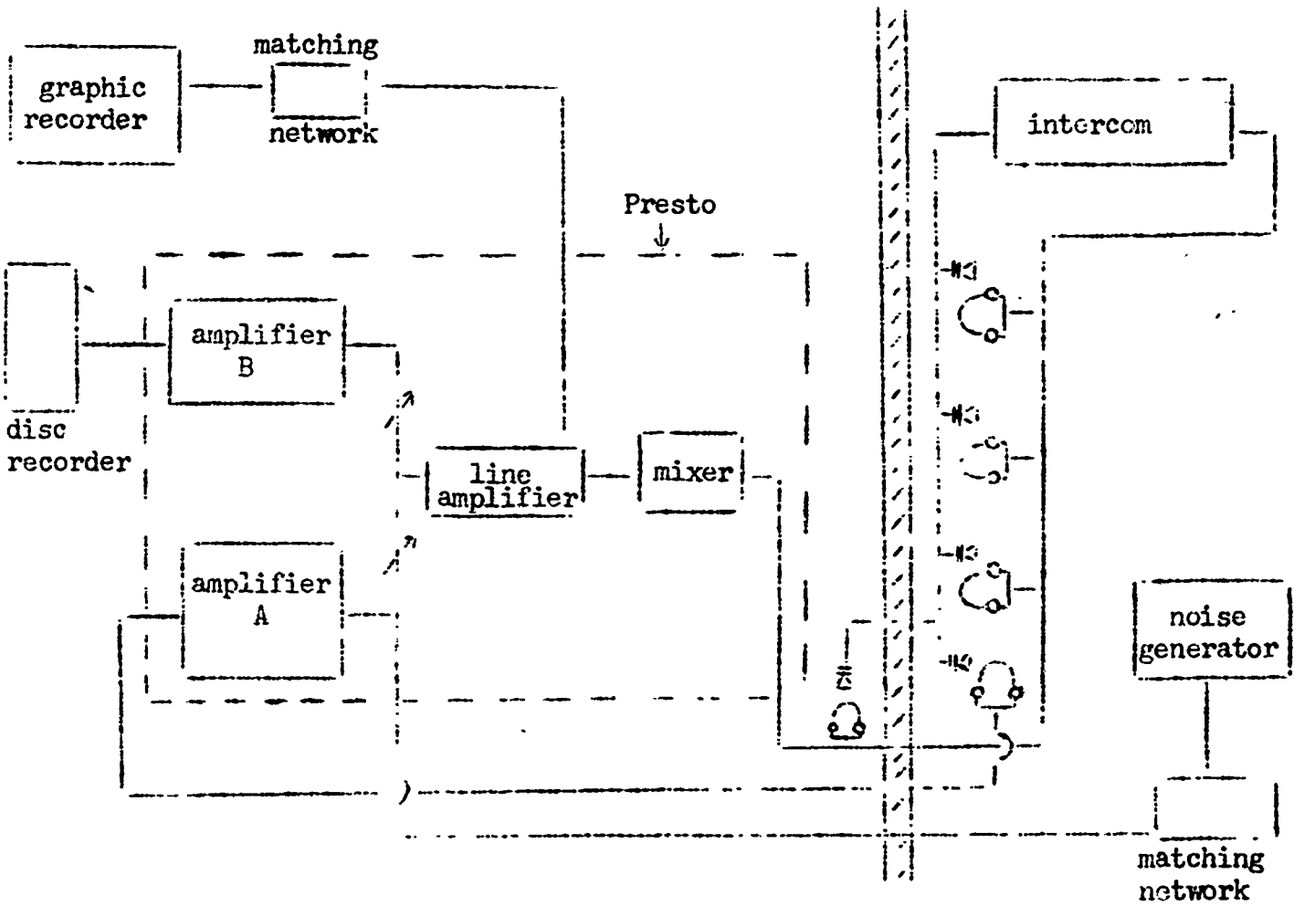

Figure 1. Diagram of the equipment used for controlling speaker's side-tone and recording intensity and signals.

open microphone in an airplane. Four conditions of side-tone strength accompanied the reading of the four lists. These were varied from list to list by adjusting the output of a Presto amplifier in the circuit. Attenuation from a constant high output of the Presto amplifier (8 db below maximum) was in steps, 0, 14, 27, and 38 db. Two of these were above and two below the "fixed" output level of the interphone amplifier in basic training planes. The lowest level produced a discernibl. side-tone only with loud talking. (The click of the microphone remained audible.) The order of side-tone conditions was rotated from speaker to speaker: 1, 2, 3, 4; 2, 3, 4, 1; 3, 4, 1, 2; etc. (See Figure 1 for diagram of "speaker" equipment.)

The microphone signal led from a mixer to a graphic level recorder and to the Presto line amplifier (for recording) and to the Presto power amplifier serving the talker's headphones.

The recordings were played back to panels of 12 listeners. The 16 subjects served as listeners. In different combinations of 12's, they comprised four listening panels. Each panel heard the 16 lists read once. No listener heard himself. Standard listener forms were used for recording the responses of listeners in the multiple-choice test. The listeners heard the recordings through headphones and with one level of amplification. Simulated airplane noise (110-114 db) filled the room. (See Figure 2 for diagram of "listener" equipment.)

Results

The speakers were progressively both more intense and more intelligible as their side-tone was diminished in intensity. The means of the two measures for the different side-tone conditions appear in Table I and Figure 3.

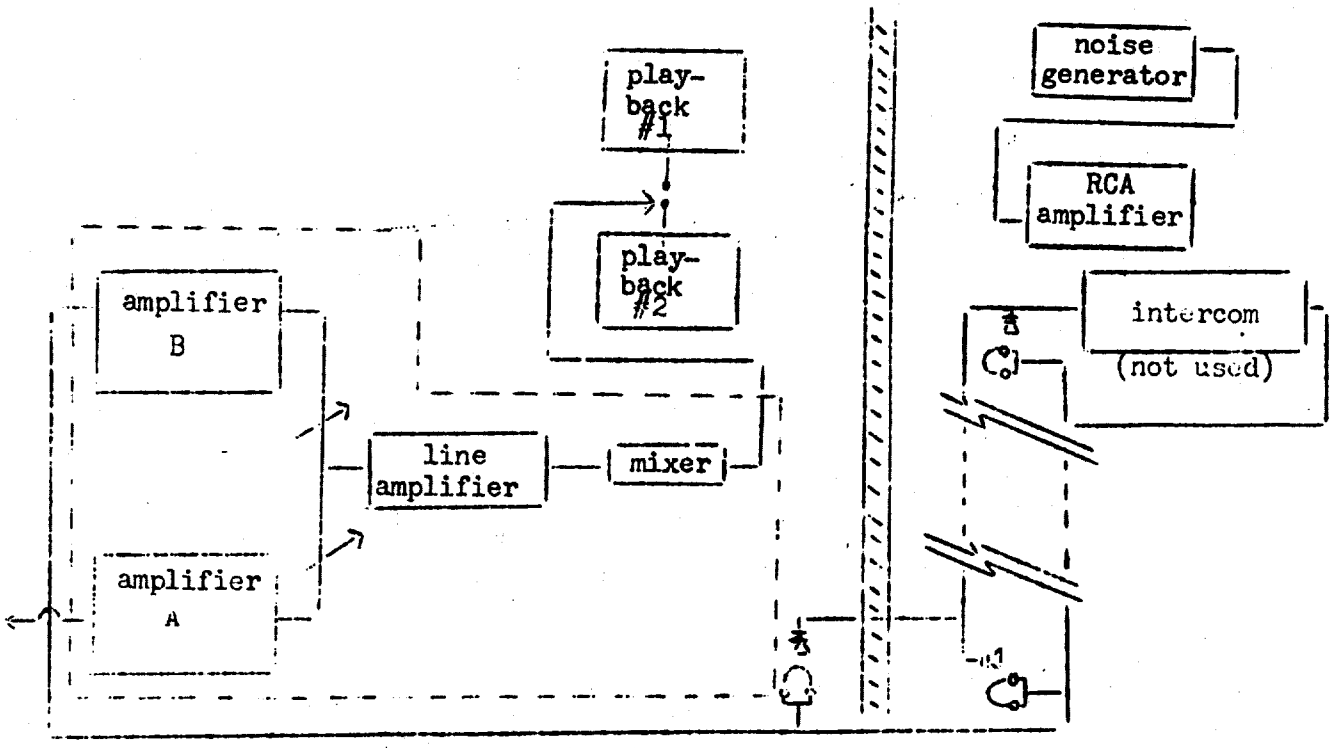

Figure 2. Diagram of the equipment for listening to recorded intelligibility tests.

The first factor under test was the effect of different side-tone levels on the intelligibility of the speakers. A simple analysis of variance, summarized in Table IIa indicated that side-tone variance was significant and listening panel variances non-significant. In other words, intelligibility scores were affected differentially by side-tone level. This analysis was performed from the intelligibility scores assigned the speakers by the four panels and represented the main analysis. In it the denominator used in the determination of the F-ratio was the interaction variance of side-tones and listening panels. Since the panels were not made up entirely of the same listeners a further investigation was made of the panels. A summary of an analysis of variance of each panel is shown in Table IIb (and with interaction-values that relate to listeners

TABLE I

Measures of intelligibility and relative intensity of speaker when talking with varying conditions of side-tone intensity. N, subjects, 16.

Side-tone condition as indicated by attenuation of full amplifier output	Mean % Intelligibility	S.D.	Mean intensity from graphic level recorder	S.D.
0 db	56.4	15.9	41.92	10.8
-14 db	62.9	11.2	48.02	7.0
-27 db	68.8	7.6	52.88	4.9
-38 db	76.3	6.0	54.89	3.3

pooled, in Table IIc.) The point of the analysis was primarily to study the relationship between the different panels and side-tonesxspeakers, and to find whether the panels were the same or different. Interactions involving listeners were of relatively small magnitude throughout. They were, therefore, combined to form error terms for assessing the significance of variations in each panel. Side-tone x speaker interaction was significantly greater than error in all panels as shown in Table IIc. Also it is apparent in the Table that variances attributed to side-tones and to speakers were of greater magnitude in each panel than that attributed to listeners.

Two tests were made to determine whether the panels were the same. Bartlett's chi-square test was applied to the mean total variation among the listening panels. This showed them to be the "same" (chi-square = 3.31; 5%, 7.82). The same test was applied to side-tone variations among the four listening panels; it showed side-tone variance to be the "same" (chi-square = 3.62; 5%, 7.82). (These are essentially the procedures that

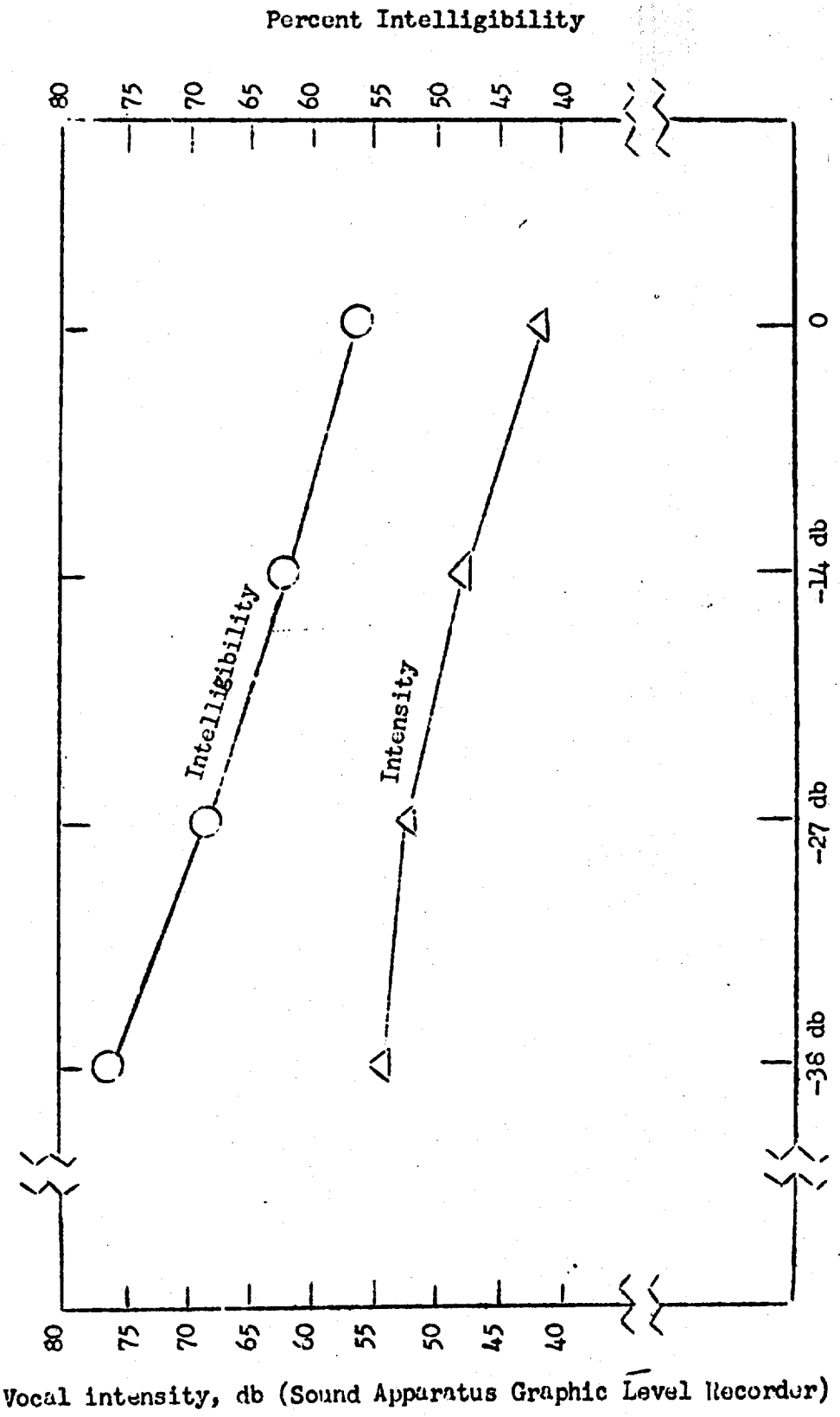

Figure 3. Mean intelligibility and intensity as functions of four levels of side-tone relative to constant high output of Presto power amplifier Intensity of side-tone in the speakers' headphones.

one would follow in determining the homogeneity of data from duplicated experiments that he might wish to combine.) The listening panels proving to be the "same", a combination error term (variance) was established by adding the sums of squares for the speaker x side-tone interaction. The interaction variance in Table IIa (3059.86) proved significantly greater than the combined error term (49.98). The significance of this value is illuminating in attributing the interaction variances to their sources and evaluating the nature of the interaction. The panel x side-tone interaction includes a large portion of the variance attributable to individual speakers-listeners, and is significantly greater than the interaction variances for these effects in the single panels. The listening panels being the same, the panels x side-tones variance represents a conservative error term for the main analysis--one in which the presence of interaction can be assumed.

The second factor under test was whether side-tone level affected intensity of voice. The analysis for this was not complicated by a listening variable. In the multiple-choice intelligibility test the speaker says three successive words (items) in a group as apple baker light and the listener's form has four choices for each of the words. There are eight such word groups in a speaker's test. The intensity of the spoken word group appears on the graphic level recording as three distinct excursions of the stylus. The median of the three intensities so represented was taken as representative of the intensity of the word group for measurements and computations of the present study; thus the mean intensities in Table I were computed from the means of eight medians for each speaker. The median intensity of each of the 24 word groups that were read by 16 speakers provided the basis for an analysis of variance: side-tones (4), median for the word groups at each side-tone (8), and

TABLE II

Summary of analysis of variance: intelligibility scores from four panels of listeners each of which heard four speakers who read intelligibility tests while hearing successively four levels of side-tones.

a. variance with all panels combined

Source of variation	d.f.	Variance
Listening panels (p)	3	5462.91
Side-tones (s)	3	38030.08
Remainder (pxs)	9	3059.86

F, V_s/V_{pxs} = 12.43 (1%, 6.99)

F, V_{pxs}/error* = 6.13 (1%, 2.94; d.f. 9 and 96 d.f.)

b. variance for each listening panel: side-tones, speakers, listeners

Source of variation	d.f.	Panel a	Panel b	Panel c	Panel d
Side-tones (s)	3	89.67	128.74	170.75	594.38
Speakers (i)	3	148.06	162.72	145.26	386.51
Listeners (l)	11	54.79	65.12	91.76	124.73
sxi	9	25.20	23.71	37.50	113.17
sxl	33	4.42	3.63	11.28	14.03
ixl	33	1.88	8.27	11.50	5.73
sxixl	99	4.30	4.11	1.78	3.34

c. same as b with listener interaction combined (remainder)

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Listeners (l)	11	54.79	65.12	91.76	124.73
sxi	9	25.20	23.71	37.50	113.17
Remainder (r)	165	7.23	4.85	5.61	5.95
F, V_{sxi}/V_r (1%, 2.50)		3.49	4.89	6.68	19.01

c. comparison of means

Mean (diff.)	t, from distributions of differences
Side-tones 1-2	2.02
2-3	2.58
3-4	4.47

(1%, 2.95; 5%, 2.13)

* See text

and speakers (16). A summary of the analysis of variance appears in Table III. The effect of the level of the side-tone upon vocal intensity is apparent. As the side-tone is lowered the intensity of the speaker increases.

The four levels of side-tones were selected arbitrarily. Although in casual tests they appeared to be equally separated this was not established. Moreover, the measures of attenuation were at the output of the amplifier and not necessarily measures of the output of the headphones. Tests for linearity, therefore, were not indicated. However, the comparisons did pro-

TABLE III

Summary of analysis of variance: vocal intensity of speakers while reading four lists of phrases (eight phrases per list), and hearing a different level of intensity of the side-tone with each list. N, speakers, 16.

a. analysis of db measurements (Sound Apparatus Graphic Level Recorder)

Source of variation	d.f.	Variance
Side-tones (s)	3	3863.16
Phrases (p)	7	12.57
Speakers (sp)	15	1050.55
sxp	21	24.08
sxsp	45	192.11
pxsp	105	14.97
sxpxsp	315	15.44
Total	511	

F, V_{sxp}/V_{sxpxsp} = 1.56 (5%, 1.61)

F, V_s/V_{sxsp} = 20.11 (1%, 4.26)

F, V_{sp}/V_{sxsp} = 5.47 (1%, 2.42)

b comparison of means

Mean (diff.)	t. from distributions of differences
Side-tone 1-2	3.23
2-3	4.01
3-4	1.86

(1%, 2.95; 5%, 2.13)

vide for a test for similarity of trend. The hypothesis under test was that alterations in side-tone level affected output of vocal intensity and speaker intelligibility score in the same manner. A summary of the analysis of trend appears in Table IV. F in the analysis was less than unity establishing the probability of similar trends in the two effects of varying side-tone levels.

TABLE IV

Summary of analysis of variance: intensity level of oral reading and intelligibility scores attending four levels of side-tone compared in trend. N, speakers, 16.

Source of variation	d.f.	Variance
Intensity vs. intelligibility scores (in)	1	8881.11
Speakers (i)	15	345.19
Side-tones (s)	3	159.94
in x i	15	68.60
in x s	3	75.86
i x s	45	13.70
i x in x s	45	83.99

F, V_{ixin}/V_{ixinxs} = less than unity

Discussion

The results of this experiment are interesting when compared with those of other experiments related to vocal intensity. It has been found that listener-speakers respond with greater intensity as they hear more intense signals. This relation obtains for all except very weak signals

and is apparent when the signals are no more than 3-4 db different in intensity. It is especially noticeable in responses to high signal levels. And it is present both when subjects hear and repeat words and when they hear and answer questions. Applying the principle to side-tones one might expect that the louder a speaker heard himself the louder he would talk. The reverse is true. When the ability to control the side-tone lies in the manipulation of the listener-speaker's own voice he talks in a manner to decrease an intense sensation at the ear and augment a weak one. The effect is comparable to the tendency of some hard-of-hearing people to talk louder as deafness progresses.

In part this is comparable to an experiment in another laboratory. Two groups of listeners listened to identical voice signals. One group was permitted to adjust the amplification of the signal to an optimal level for intelligibility; the other group always heard intense signals. There were two results: the listeners who were able to do so attenuated the signal level; the listeners who heard the signals with greater intensity made the higher listener scores. Similarly in the present study, as the speakers avoided unpleasant side-tones they became less intelligible to listeners. The experience of comfort and the self-evaluation of optimal intensity for communication are not valid guides.

Conclusion

Speakers who hear their own voices over headphones concurrently with their talking adjust their vocal intensity in a manner that compensates for the level of the side-tone. The more intense the side-tone, the less intensely the speaker talks. The relationship between the two values is apparently close, the same in trend. This affects the degree to which he is understood. In the interests of good communication, the side-tone

should be attenuated as much as possible.

Appendix: Notes affecting intelligibility testing

This study provided data about two questions relevant to testing intelligibility. The first may be a matter of general concern in such testing. Under circumstances such as presented in this study, with a listener hearing the same lists of words three times, including lists that he has previously read, does familiarity with the test affect the scores that he assigns to the speakers? Apparently not. The group of listeners gave the same mean scores to the lists that they had read and to the lists they had not read--61.4 in both instances.

The second question is relevant only to the multiple-choice intelligibility test. In reading three words in a test phrase does a speaker talk with different intensity when saying the first, second, and third words. The summary of an analysis of variance was made of the intensity of 16 speakers reading four tests each, with eight word groups per test. Although, as would be expected, there was significant variation among speakers, the F-ratio for items within word groups was non-significant. The main effects in the analysis were speakers and word items and the remainder was the interaction between these two.